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1. Your reference — itc.1591.uk.nm/ja.d

2. Patent application number *(The Patent Office will fill in this part)* — **0201223.5**

3. Full name, address and postcode of the or of each applicant *(underline all surnames)*

   Incorporated Technologies (Holdings) Limited
   1 Pavilions
   ALLOA
   Clackmannanshire
   FK10 1TA

   Patents ADP number *(if you know it)* — 8253486001

   If the applicant is a corporate body, give the country/state of its incorporation — UK

4. Title of the invention — Kiosk Technology Kit

5. Name of your agent *(if you have one)* — Kennedys

   "Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*

   Floor 5, Queens House
   29 St Vincent Place
   GLASGOW
   G1 2DT

   Patents ADP number *(if you know it)* — 8036758002

6. If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number

Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*

7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application

Number of earlier application	Date of filing *(day / month / year)*

8. Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:*
   a) any applicant named in part 3 is not an inventor, or
   b) there is an inventor who is not named as an applicant, or
   c) any named applicant is a corporate body.
   See note (d)) — Yes

9. Enter the number of sheets for any of the following items you are filing with this form. Do not count copies of the same document

Continuation sheets of this form	
Description	10
Claim *(s)*	
Abstract	
Drawing *(s)*	4 + 4

10. If you are also filing any of the following, state how many against each item.

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Translations of priority documents	
Statement of inventorship and right to grant of a patent *(Patents Form 7/77)*	
Request for preliminary examination and search *(Patents Form 9/77)*	
Request for substantive examination *(Patents Form 10/77)*	
Any other documents *(please specify)*	

11. I/We request the grant of a patent on the basis of this application.

Signature Kennedys
KENNEDYS

Date
18 January 2002

12. Name and daytime telephone number of person to contact in the United Kingdom

Jim Adams 0141 226 6826

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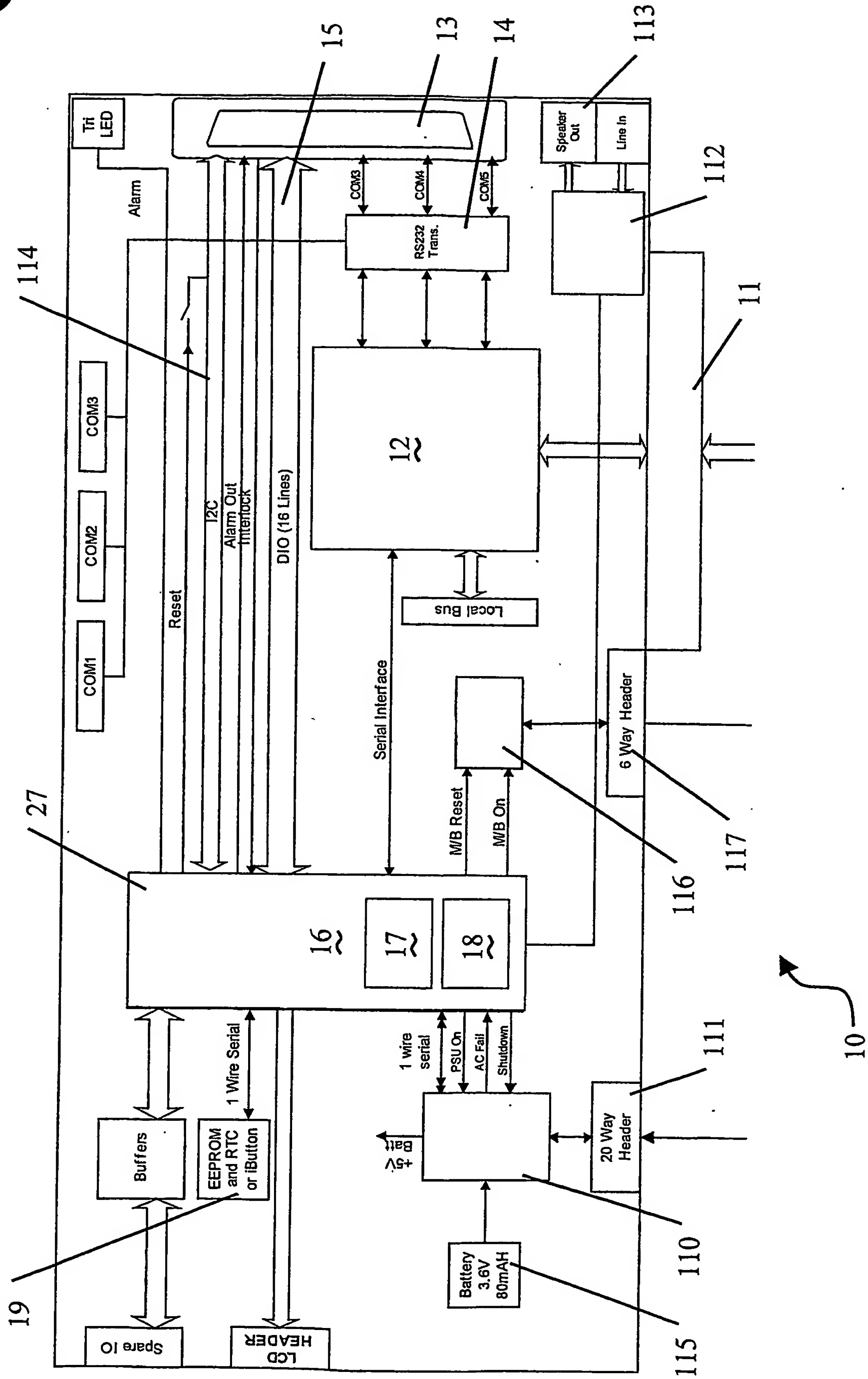
Tri LED
Alarm
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COM2
COM3
Reset
I2C
Alarm Out
Interlock
DIO (16 Lines)
COM3
COM4
COM5
RS232 Trans.
12
Local Bus
Serial Interface
Speaker Out
Line In
6 Way Header
M/B Reset
M/B On
16
17
18
Buffers
EEPROM and RTC or iButton
1 Wire Serial
1 wire serial
PSU On
AC Fail
Shutdown
+5V Batt
20 Way Header
Battery 3.6V 80mAH
Spare IO
LCD HEADER
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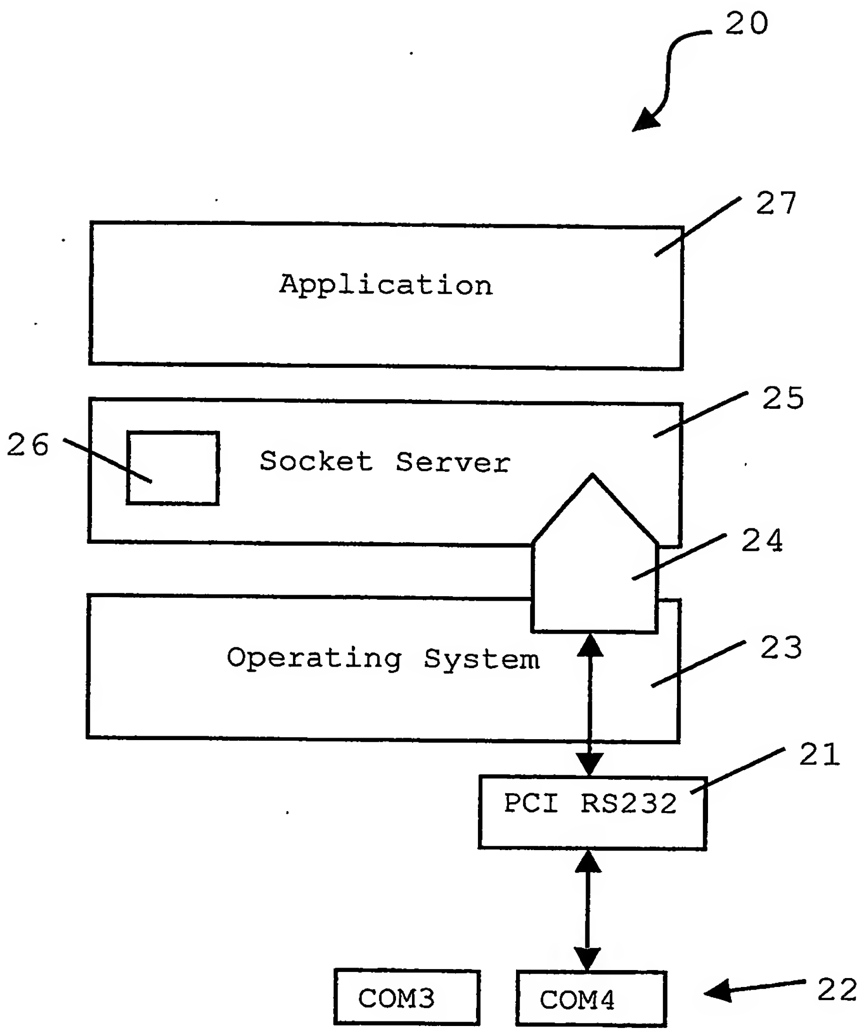
Fig. 1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Application
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Socket Server
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Operating System
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21
PCI RS232
COM3
COM4
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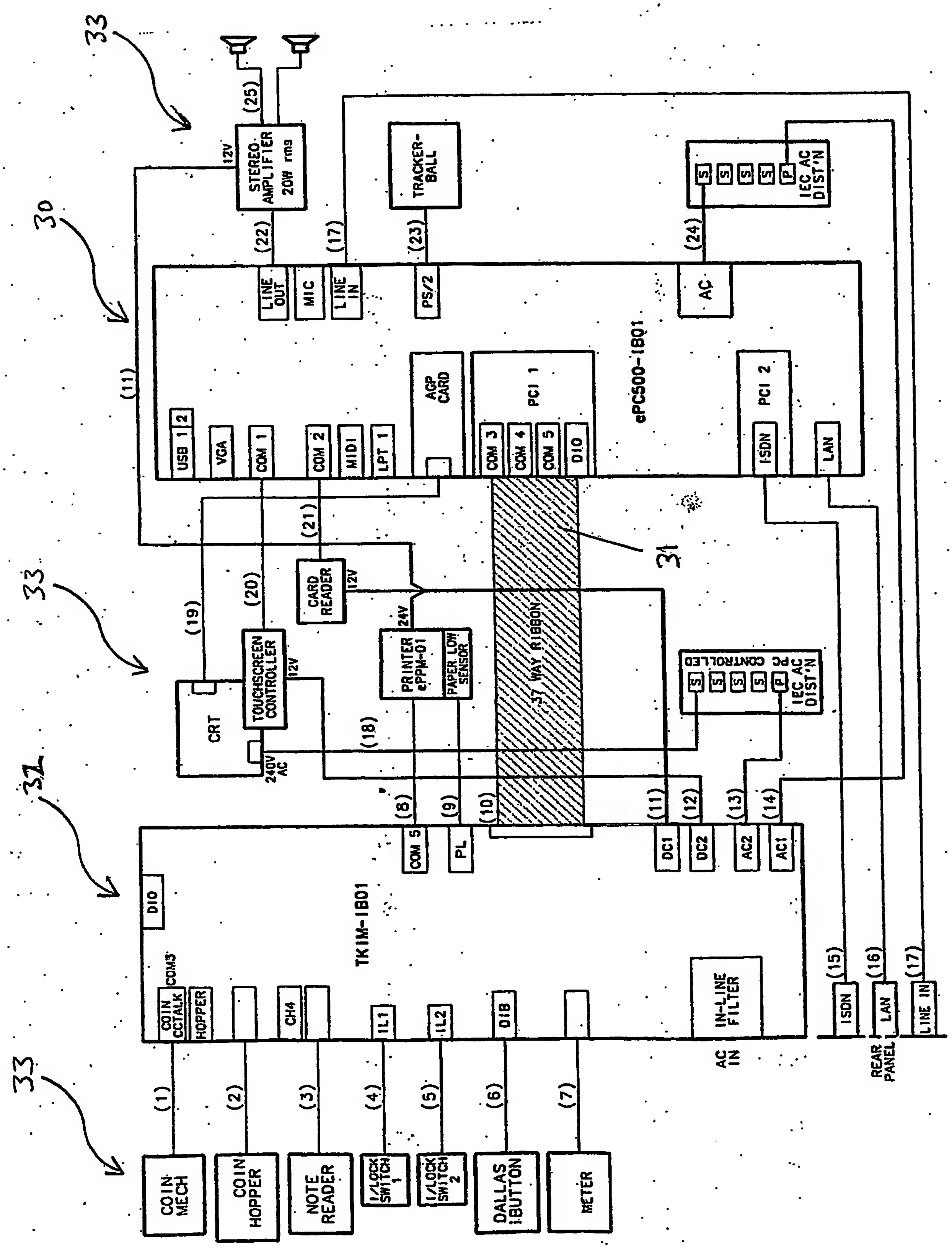
Fig. 2

3/4



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32
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STEREO AMPLIFIER 20W rms
12V
TRACKER-BALL
IEC AC DIST'N
LINE OUT
MIC
LINE IN
PS/2
AC
ePC500-IB01
AGP CARD
PCI 1
PCI 2
USB 1 2
VGA
COM 1
COM 2
MIDI
LPT 1
COM 3
COM 4
COM 5
DIO
ISDN
LAN
CARD READER
37 WAY RIBBON
PRINTER ePPM-01
PAPER LOW SENSOR
24V
TOUCHSCREEN CONTROLLER
CRT
240V AC
PC CONTROLLED IEC AC DIST'N
TKIM-IB01
DC1
DC2
AC2
AC1
PL
COIN CCTALK
COM3
HOPPER
CH4
IL1
IL2
DIB
IN-LINE FILTER
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COIN HOPPER
NOTE READER
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DALLAS iBUTTON
METER
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Fig. 3

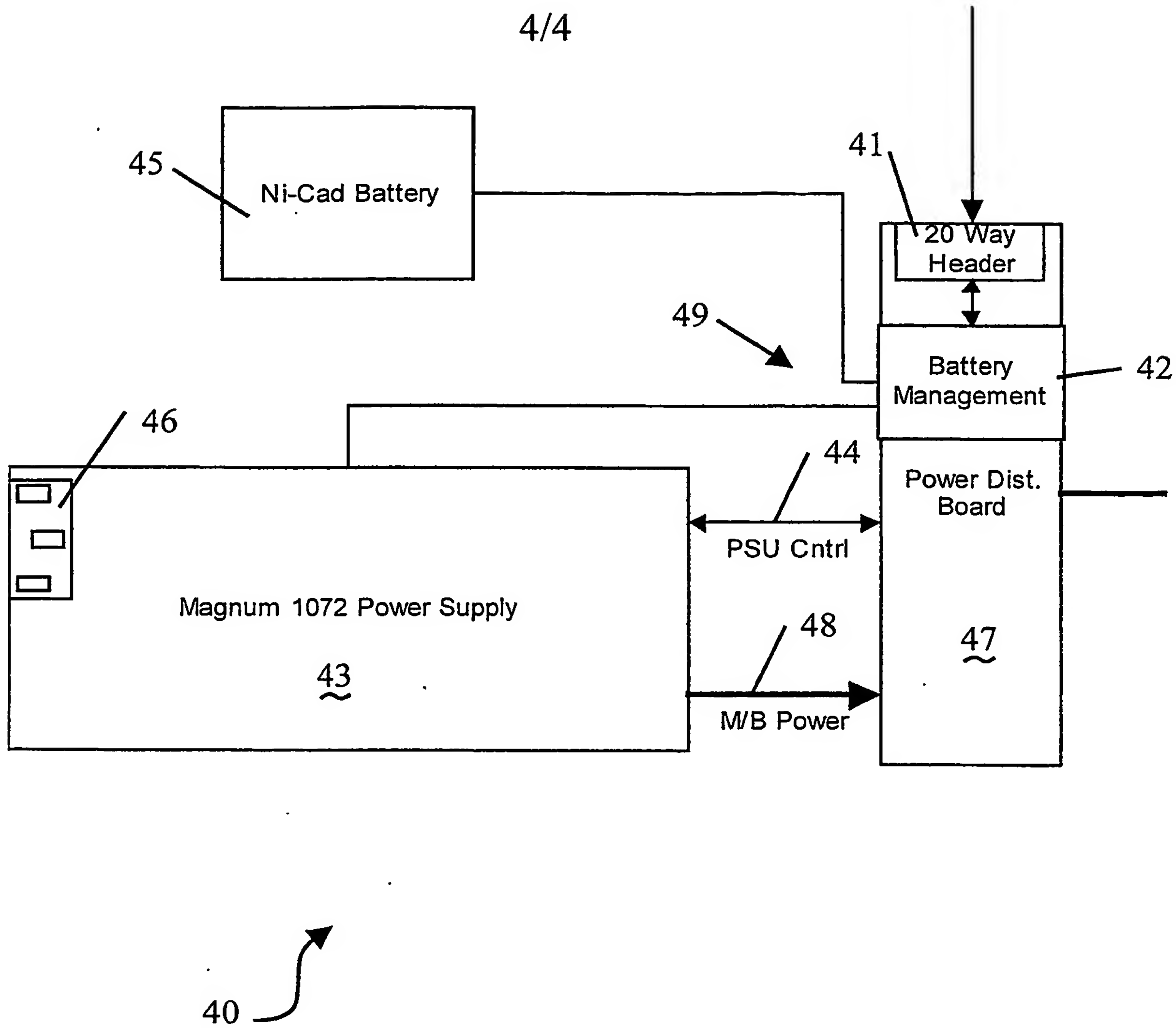
45
Ni-Cad Battery
41
20 Way Header
49
Battery Management
42
46
44
Power Dist. Board
PSU Cntrl
Magnum 1072 Power Supply
48
47
43
M/B Power
40

Fig. 4

Kiosk technology kit

This invention relates to computer systems, in particular, interfacing personal computers (PCs) to peripherals in a multi-media kiosk applications.

In an embedded environment such as a kiosk, a PC needs to be configured and supported with additional hardware to provide system reliability and robustness and multiple device interfaces.

In the prior art systems are known for embedding standard PC hardware within a kiosk application. Such a system is provided by Coynet UK Limited that uses hardware containing an embedded processor on a control circuit board programmed to influence the PC in a kiosk application. During initialisation of the PC, or if the PC control program is not in operation, the processor automatically detects potential vulnerability in the system and automatically takes steps to prevent use of this system until it is once more stable and secure.

A significant problem with this and other known prior art solutions to is the inefficient use of input/output (I/O) ports of the PC. I/O ports such as serial RS-232 ports are needed for communication with kiosk peripherals such as coin mechanisms, note readers, meters for counting, card readers and printers.

Even more ports, including RS-232 and motherboard expansion slots (e.g. PCI, Peripheral Component Interconnect) are needed for hardware used to monitor the health and security of the PC, for example, controlling the power supply and monitoring the software and hardware state of the PC. An uninterruptable power supply (UPS) is desirable for monitoring and control of power to the motherboard and this is typically monitored and controlled by the motherboard itself using an RS-232 port. A watchdog capability is useful to monitor the state of the PC and this typically requires a processor unit (e.g. a microcontroller) external to the motherboard connected to the motherboard via a RS-232 port and other connectors on the motherboard. In a kiosk system it is desirable to have digital Digital Input/Output (DIO), and this typically is achieved by using a PCI slot on the motherboard with a DIO card or by having an RS-232 port connection to a DIO device. An embedded system can be further improved with the ability to store customer specific data in non-volatile memory in order to provide security features, and this is typically achieved with the use of a PCI slot, an RS-232 port or a parallel port. Another desirable features is output to an amplifier and speaker which is typically done through a PCI slot with a sound card. Communication with other processor such as using the I^2C (Inter-IC) bus would typically use another

PCI slot the motherboard for a communications adapter card. The I²C bus is a standard two-wire serial bus used in a variety of microcontroller-based embedded applications for control, diagnostics and power management. Yet another feature possible in an embedded system is monitoring of the state of batteries connected to the uninterruptable power supply, and this could be achieved using hardware connected to another port of the PC.

It can be seen that there are not enough ports on a standard PC motherboard to supply all of the connectivity to kiosks peripherals and for all of the desirable functions listed above. The conventional approach to this problem is to provide port expansion hardware, typically occupying a PCI slot with a bank of UARTs (Universal Asynchronous Receiver/Transmitters) controlled by a microcontroller. The problem with this approach is the cost and the complexity of software event handlers needed to control all of the peripherals attached via the bank of UARTs. It is not possible with this approach to use a standard plug and play architecture for added applications on the host PC because special event handler code needs to be written at the microcontroller level or a special abstraction layer and API (Application Programming Interface) needs to developed.

It would be advantageous to provide an architecture and a control module that fulfilled all of the desirable peripheral connection needs and all of the control functions for a PC in an embedded application such as a kiosk.

It is an object of the present invention to provide a control module and architecture that occupies one expansion slot on a PC motherboard while providing a plurality of functions and ports needed for embedding a motherboard in a kiosk application environment.

According to a first aspect of the present invention there is provided a control module comprising:

- a motherboard bus connector
- a motherboard bus to serial port bridge module
- at least one serial port connector

characterised in that the control module further comprises a processor module.

According to a second aspect of the present invention there is provided a system comprising a motherboard and a control module in accordance with the first aspect.

Preferably said control module communicates to the motherboard through said motherboard bus connector.

Preferably said control module provides at least one peripheral control port for said motherboard.

Preferably, the microcontroller unit comprises a monitoring means for monitoring the state of said motherboard.

Typically, the monitoring means further monitors the state of software running on said motherboard.

Preferably, the processor module has a battery power supply separate from the PC power supply.

Preferably, the processor module further comprises a power supply monitoring means for monitoring the state of a power supply supplying said motherboard.

Preferably, event handlers for said at least one serial port are provided by a socket server layer in between the application layer and the operating system layer of the software executing on the motherboard.

More preferably, event handlers for said at least one peripheral control port are provided by a socket server layer in between the application layer and the operating system layer of the software executing on the motherboard.

According to a third aspect of the present invention, there is provided a system for conditioning a back-up battery comprising a battery and a power supply characterised in that the electrical connection between said battery and power supply is diverted through a battery management circuit that is controlled by a microcontroller.

In order to provide a better understanding of the present invention, an embodiment will now be described by way of example only and with reference to the accompanying figures in which:

- Figure 1 illustrates in schematic form a control module in accordance with the present invention;

- Figure 2 illustrates in schematic form a software architecture in accordance with the present invention; and

- Figure 3 illustrates in schematic form a system including a control module, a peripheral interface module and peripherals in accordance with the present invention.
- Figure 4 illustrates in schematic form a power supply system in accordance with the present invention.

The invention is a card for connecting to a PC motherboard that functions to provide serial port expansion, digital I/O port (DIO) expansion and control functions for a PC in an embedded environment.

With reference to Figure 1, the control module 10 is shown comprising a PCI connector 11, a PCI/RS-232 bridge chip 12 comprising four UARTs with output to a single multifunction connector 13 that includes three RS-232 ports 14 and two eight-bit DIO ports 15.

One RS-232 port from the bridge chip is connected to a processor module which is a microcontroller unit 16 that includes FLASH EEPROM memory 17 and boot loader ROM 18.

A Dallas iButton 19 from Dallas Semiconductor Corp. is provided for measuring temperature, providing further non-volatile memory (EEPROM), a real time clock and a unique serial number. The serial number is used for provision of security features, including software licence verification, thus acting as a 'dongle'.

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PTO/SB/16 (8-00)
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PROVISIONAL APPLICATION FOR PATENT COVER SHEET

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53(c).

INVENTOR(S)

Given Name (first and middle [if any])	Family Name or Surname	Residence (City and either State or Foreign Country)
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THIERRY	BRUN	PARIS, FRANCE
SERVE	PLOUMEN	LIMBURG, NETHERLANDS

☒ *Additional inventors are being named on the 2 separately numbered sheets attached hereto*

TITLE OF THE INVENTION (280 characters max)

LIGHTWEIGHT AND TAILORABLE VEHICLE DYNAMICS SYSTEM WITH OPTIMIZATIONS FOR LIGHTWEIGHT AND HYBRID-ELECTRIC AUTOMOBILES

Direct all correspondence to: **CORRESPONDENCE ADDRESS**

☒ Customer Number ______ → *Place Customer Number Bar Code Label here*

OR *Type Customer Number here*

☒ Firm *or* Individual Name	SHAW PITTMAN LLP
Address	
Address	1650 TYSONS BOULEVARD
City	MCLEAN — State VA — ZIP 22102
Country	USA — Telephone 703/770-7900 — Fax 703/770-7901

ENCLOSED APPLICATION PARTS *(check all that apply)*

☒ Specification *Number of Pages* 33 ☐ CD(s), Number

☐ Drawing(s) *Number of Sheets* ☐ Other (specify)

☐ Application Data Sheet. See 37 CFR 1.76

METHOD OF PAYMENT OF FILING FEES FOR THIS PROVISIONAL APPLICATION FOR PATENT *(check one)*

☒ Applicant claims small entity status. See 37 CFR 1.27.

☐ A check or money order is enclosed to cover the filing fees

☐ The Commissioner is hereby authorized to charge filing fees or credit any overpayment to Deposit Account Number

☐ Payment by credit card. Form PTO-2038 is attached.

FILING FEE AMOUNT ($) $80.00

The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.

☒ No.

☐ Yes, the name of the U.S. Government agency and the Government contract number are: ______

Respectfully submitted,

SIGNATURE ______ Date 01/23/02

TYPED or PRINTED NAME MICHAEL D. BEDNAREK — REGISTRATION NO. *(if appropriate)* 32,329

TELEPHONE 703/770-7606 — Docket Number: HCI0006-PROV.

USE ONLY FOR FILING A PROVISIONAL APPLICATION FOR PATENT

PROVISIONAL APPLICATION COVER SHEET
Additional Page

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INVENTOR(S)/APPLICANT(S)		
Given Name (first and middle [if any])	Family or Surname	Residence (City and either State or Foreign Country)
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DAVID	CRAMER	SAN CARLOS, CA
DAVID	WAREING	CAMBRIDGESHIRE, UNITED KINGDOM
DAVID	TAGGART	SAN CARLOS, CA

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Provisional Patent Application: Lightweight and Tailorable Vehicle Dynamics System with Optimizations for Lightweight and Hybrid-Electric Automobiles

Primary Inventor: Timothy Moore (Hypercar, Inc.)

Other Inventors: Chris Wright (TWR), Thierry Brun (TWR), Serve Ploumen (FKA), David Cooper (TWR), David Cramer (HI), David Wareing (TWR), David F. Taggart (HI)

Brief Description:

The lightweight and tailorable vehicle dynamics system described herein was designed specifically to perform in a synergistic manner with a full sized but lightweight automobile design to efficiently and cost-effectively provide consistent performance over a broad range of vehicle payload and driving conditions. . The dynamics system emphasizes the application of digital information management and control, advanced materials, and a modular design perspective that contributes directly to its value as a stand-alone system of an automobile, and its value in the context of enabling the desired performance of the entire vehicle. The system consists of semi-active independent suspension at each corner of the vehicle, electrically-actuated carbon-based disc brakes, modular rear corner drivetrain hardware and suspension, and a novel approach to electrically actuated and controlled steering. Unique features include energy-efficient active ride height, attitude, roll stiffness, and damping control, active tire contact patch monitoring and control, and lightweight, high-performance braking. Components are fabricated from materials that uniquely meet the system and lifecycle requirements. .

Advantages:

Vehicle Dynamics: The challenge of achieving desirable ride, handling, and stability of a full size vehicle with very low mass is significant. Vehicle dynamics are very sensitive to the ratio of sprung mass to unsprung mass, amount and position of the payload, and the components, and their configuration and function applied in the suspension at each corner of the vehicle. The dynamics system described herein deals with that challenge in a unique way that overcomes many historical shortcomings of lightweight vehicle design.

Mass: The combination of the materials used, the design and selection of the components, innovative use of digital control, and low overall vehicle mass contribute to a significant reduction in the mass of the dynamics system discussed herein compared to the dynamics system of a conventional and equivalently sized automobile. The design also eliminates some minor components while permitting the use of certain lightweight components that would not otherwise be appropriate for application outside of vehicles driven by professional drivers.

Durability: The considered material selections and exploitation of digital electronics contribute to a dynamics system that will surpass the lifetime of the dynamics system of a conventional and equivalently sized automobile.

Modularity/Tailorability: The integrated design approach to the rear corners and the use of digital electronics throughout the system will provide a high degree of inherent modularity and tailorability currently not practical in conventional equivalently sized automobiles.

Features of the innovation:

- The specific approach to the use of advanced composites in the suspension components to reduce their mass and enable beneficial structural integration without compromising affordability or durability
- The unique application and integration of semi-active pneumatic springs and active electromagnetic damping as suspension struts to accommodate a wide range of variation in the ratio of payload-to-gross vehicle mass, variation in the position of the payload's center of gravity, while reducing the compromises in handling vs. ride/comfort typical of conventional systems, permitting control of ride height and active damping with minimized energy consumption, and expanding capability for negotiating rough terrain
- The incorporation of semi-active pneumatic anti-roll control to permit adjustment of roll stiffness in response to changes in payload or gross vehicle mass, vehicle speed, roughness of terrain, and driver-selectable preferences
- The replacement of a conventional steering rack with an innovative bell-crank steering linkage, dual electric steering motors, and digital by-wire control
- The degree of integration of the rear suspension component with the structural mounting and casing for electric traction motors, transmission (constant-mesh reduction gears), knuckle, bearing, and spindle or hub
- The use of electrically actuated calipers with carbon/carbon brake pads and rotors to accommodate the unique material and braking characteristics of the carbon/carbon materials, thereby reducing mass, providing exceptional performance, and making carbon-carbon pads and rotors feasible in consumer and commercial automotive products by presenting a consistent and predictable relationship between driver input and deceleration of the vehicle
- The use of active tire pressure monitoring and control to manage contact patch quality and thus to a large degree, the vehicle's ride, handling, and stability in a wide range of environmental conditions and varying driver competence
- The integrated control and coordination of suspension, to collectively provide dynamic stability control in response to either destabilization by external forces (aero dynamic or road surface inputs) or in attempting to best realize driver intentions in the context of traction-limiting road surfaces or limits of vehicle capability in extreme maneuvers

Operational scenarios for the integrated system:

1. Adjustment of suspension, steering, and brakes for a change in payload mass and distribution:

   As additional passengers or payload are added, a change from the current setting of static vehicle ride height is detected by the position transducers in the electromagnetic suspension rams (the dampers) at each corner of the vehicle. In response to this sensor input, the control system adds air pressure to both the pneumatic springs and the pneumatic anti-roll links. The default stiffness of the electromagnetic dampers is also adjusted accordingly. This maintains consistent ride height, spring-rate natural frequency, and default stiffness for anti-roll and dampers. These component subsystems would, at the same time, be optimized for mass distribution. If, for example, all payload were added at the right rear corner, the rear springs

would be adjusted more than the front, and the right rear even more still, until the vehicle height at each of the four corners was returned to what it was when the vehicle last came to rest (allowing for one or more wheels to be on a raised or depressed feature of the terrain). Additionally, the default stiffness for the rear anti-roll link and dampers would be adjusted more than the front to maintain designed under/over-steer characteristics, regardless of any subsequent dynamic actuation of chassis systems to further enhance vehicle stability.

The data from the suspension position transducers would also be used to calculate the change in overall vehicle mass from its curb mass (unladen state). The degree of electric steering "assist" (only perceived as such, since there is no physical linkage between the steering wheel or other input device and the steering actuators), will be adjusted to provide the driver with consistent steering feel and effort, regardless of changes in payload. (As is the case with some relatively conventional systems, responsiveness to steering effort would also varied according to vehicle speed to facilitate parking maneuvers while effectively damping driver input at higher speeds to enhance stability.)

The braking system will automatically compensating for overall vehicle mass along with brake temperature, moisture content, and other factors, simply by providing the brake caliper force required to consistently match driver inputs to a corresponding factory-specified vehicle deceleration. However, the data regarding distribution of payload mass will be used in addition to adjust the proportioning of brake actuation, thus matching brake torque distribution to relative traction at each wheel. (This is the base distribution before activation of continuously-variable dynamic torque control at each corner to prevent wheel lock-up.)

2. Absorption of bump on the outside edge of a turn while cornering at highway speeds on an otherwise smooth surface:

   As highway speeds (*e.g.*, greater than 50 mph) were approached, the control system would have slightly lowered the vehicle height and gradually increased both the pneumatic stiffness of the semi-active anti-roll links and the default stiffness of the electromagnetic dampers in proportion to the averaged vehicle speed (*e.g.*, over 15 sec). The automation of this adjustment is based on the underlying assumptions that the size of allowable bumps on high-speed roads is relatively smaller, and that as vehicle speed increases, minimization of body roll becomes more desirable as part of maintaining vehicle stability. The primary anti-roll stiffness (*e.g.*, for all but *very* short-duration transient inputs) will thus have been set via the relatively slow-acting semi-active pneumatic link in the anti-roll system. As a turn is initiated, the electromagnetic dampers will then augment the anti-roll system by stiffening on the side of the vehicle towards the outside of the turn. The degree of change in electro-magnetic damping will be continuously adjusted as necessary in sub-millisecond iterations so as to enhance rather than upset vehicle stability. When a bump, moderate or severe, is encountered the damper at that wheel will rapidly soften to allow the wheel to ride up over the bump. Because the dampers are electromagnetic, this can be accomplished in under a millisecond, which equates, at 60 mph for example, to an appropriate reaction before the bump has entered less than about 10–15% into the tire contact patch. If the bump (or dip) is of significant height (or depth) and the same input is not also measured and similarly dealt with at the opposite wheel, thus signifying a one-wheel bump, then the damper at the opposite corner will simultaneously stiffen to counter the transfer of the bump input across the vehicle through the anti-roll link. While the coupling of the anti-roll link will, at speed, raise the effective spring rate at the corner where the one-wheel bump is introduced, the

bump input will have been isolated at that corner for the purpose of ride comfort without the typical compromise of anti-roll stiffness and thus vehicle stability.

3. Stability control with transient cross-wind gust or extreme evasive driver inputs (steering and/or braking or accelerating):

   Body roll and/or change in trajectory as detected by suspension position transducers and yaw sensors, respectively, would be the initial result of an aerodynamic input sufficient to upset vehicle stability. In response to sensor data, the integrated control system would modify distribution of suspension damping and drivetrain torque to stabilize the vehicle. If needed, in extreme cases, regenerative and/or friction braking torque would also be selectively applied or redistributed (if the driver had already initiated a braking event). Stiffening the appropriate electromagnetic suspension dampers, again on a sub-millisecond basis, would counter the transient body roll torque while changes in distribution of wheel torque inputs would counter increases in tire slip angle.

   In the case of an extreme evasive maneuver that might otherwise destabilize the vehicle by exceeding the limits of traction, suspension dampers, brakes, and drivesystem torque at each corner would be coordinated to best realize driver intent (as determined by steering and braking or acceleration inputs). As discussed above for aerodynamic inputs, rapid damper adjustments would augment body roll control and rapid adjustment (including reduction or addition) of drivesystem torque at each wheel would at least partially offset changes in tire slip angle. If the vehicle trajectory continued to diverge from the intended course given by driver input, selective application of friction brakes would be used as an additional corrective measure.

   Because the system is fully networked, the dynamics controller has access to brake torque and wheel speed data along with rate of deceleration, suspension position, steering angle, and yaw angle. The control system would seek to provide the closest possible match to driver intent without allowing the vehicle to enter an uncontrollable skid, slide, or spin. Since the brake calipers are electrically-actuated, just as the suspension dampers (and drivesystem, when applying this innovation in a hybrid-electric or similar vehicle) are, the braking caliper force can be continuously and independently varied at each corner of the vehicle in a fraction of a millisecond. This would be in response to driver input, actual brake torque (detected by a strain gauge in the caliper mount), wheel speed (detected by a hall-effect sensor), vehicle deceleration (data from air-bag system *g* sensor), and commands from the vehicle dynamics controller. Given the semi-active optimization of ride height, spring rate, and anti-roll stiffness for vehicle payload mass and distribution and speed, the performance potential of carbon-based brakes, and the continuously variable and exceptionally rapid response of electromagnetic dampers and brake calipers, the resulting stability-control capability of this networked chassis system should exceed conventional systems by a significant margin.

Illustrations:

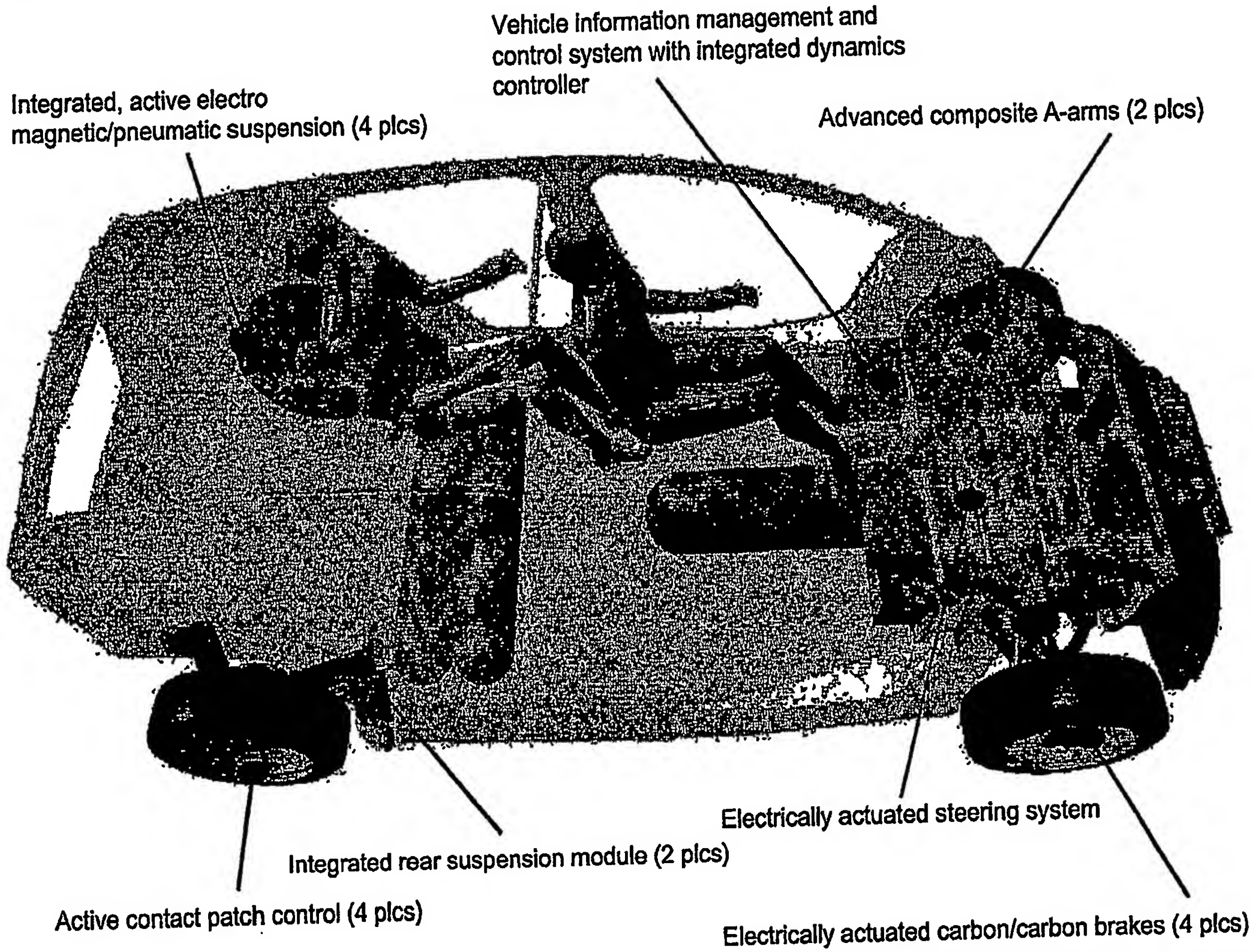

Figure 1: Schematic layout of vehicle dynamics system identifying key system elements that together comprise the subject Invention

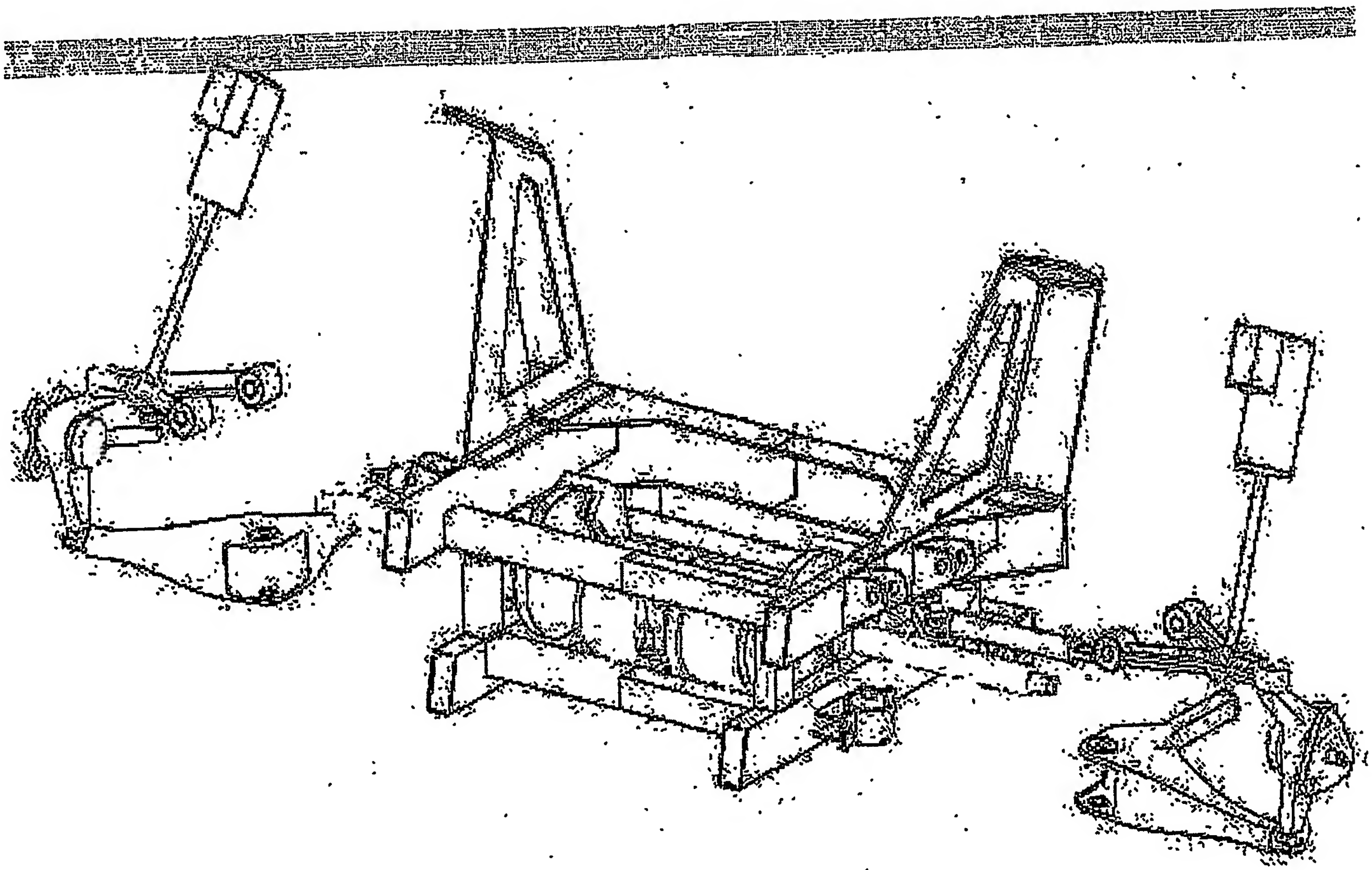

Figure 2: Front end of vehicle dynamics system showing suspension components and steering linkage in relation to subframe to which they are attached

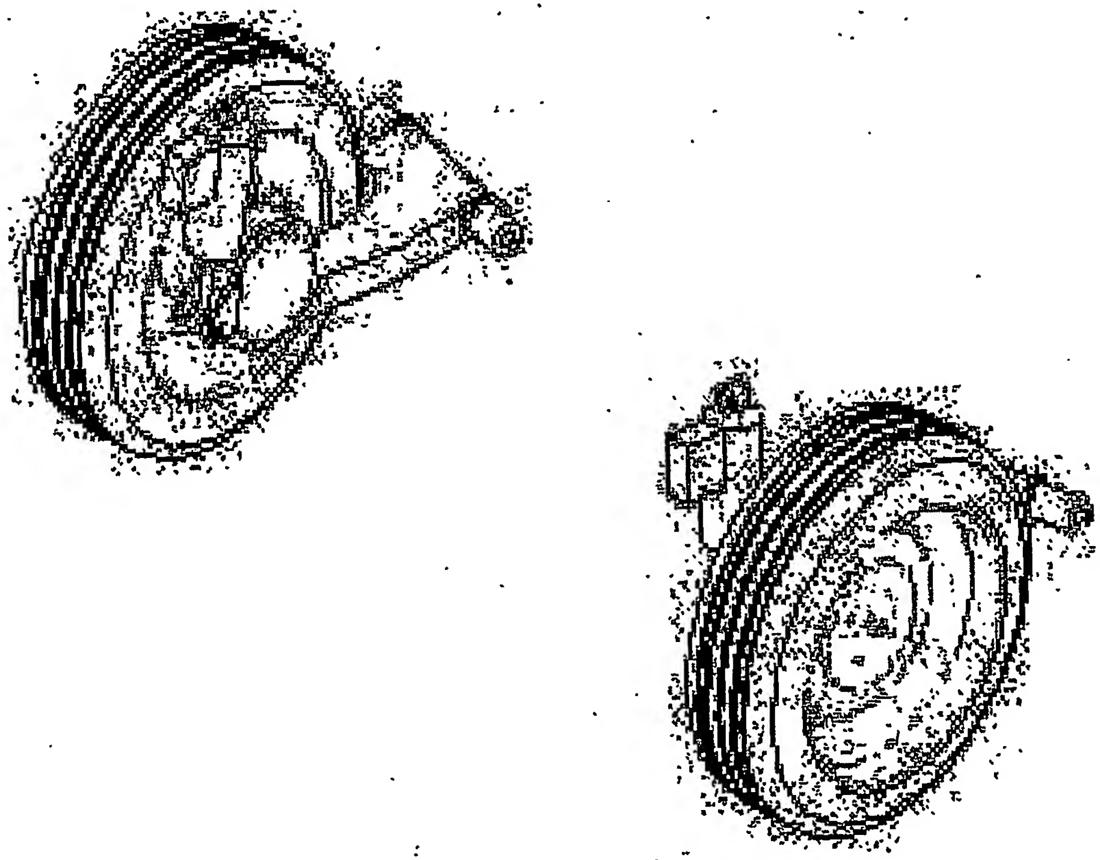

Figure 3: Rear end of vehicle dynamics system showing modular rear suspension component and active electromagnetic/pneumatic suspension strut attached to the rear wheels

System Element: Lightweight, Affordable, Electrically Actuated Steering System for Automobiles

Primary Inventor: Thierry Brun (TWR)

Other Inventors: Chris Wright (TWR), David Cooper (TWR), Timothy Moore (HI)

Brief Description:

This system element consists of electrically actuated steering with no mechanical link between the driver and steered wheels. Dual electric motors are used to apply steering force to the wheels through a set of low cost and lightweight bell cranks and tubular composite mechanical links. This design enables continuously-adjustable, high-performance steering dynamics and maintenance of Ackerman angle over a range of vehicle ride heights, in a modular, energy-efficient, and relatively low cost package. It also enables alternatives to the conventional steering column.

Advantages:

Electric by-wire steering has a number of benefits over a conventional system. The deletion of a conventional steering column removes weight and cost and is also a safety improvement as the column does not intrude into the passenger cabin. Not having a steering column and rack also frees up packaging space in the front end of the vehicle, enabling other technologies and efficiencies to be exploited. The unique linkage design also overcomes the problems of producing sufficient Ackerman in the system, which is crucial to overall vehicle efficiency and minimizing abnormal tire wear. In particular, the required links are designed to minimize loads on the bearings and joints, which means lighter and cheaper joints can be used. In addition, the links are designed to minimize frictional energy due to non-optimal transfer angles. As the steering is a pure by-wire technology, this could be integrated into the vehicles central information management and control system so that steering input, speed, and feel could all be adjusted according to the dynamic and environmental conditions that prevail, as well as to the driver's preferences. Another advantage of this system over a conventional one is that it would be easier to provide for both left hand and right hand drive versions of the vehicle.

Features of the innovation:

The electrically actuated steering system replaces a conventional steering rack of various configurations and enables both fault tolerance and full digital integration with the vehicles dynamic controller through actuation by dual electric motors. The important aspects of the design are the use of two electric motors, digital control of those motors, the configuration of the steering linkage, the design of the components comprising that linkage, and the steering performance attributes they provide.

Illustration:

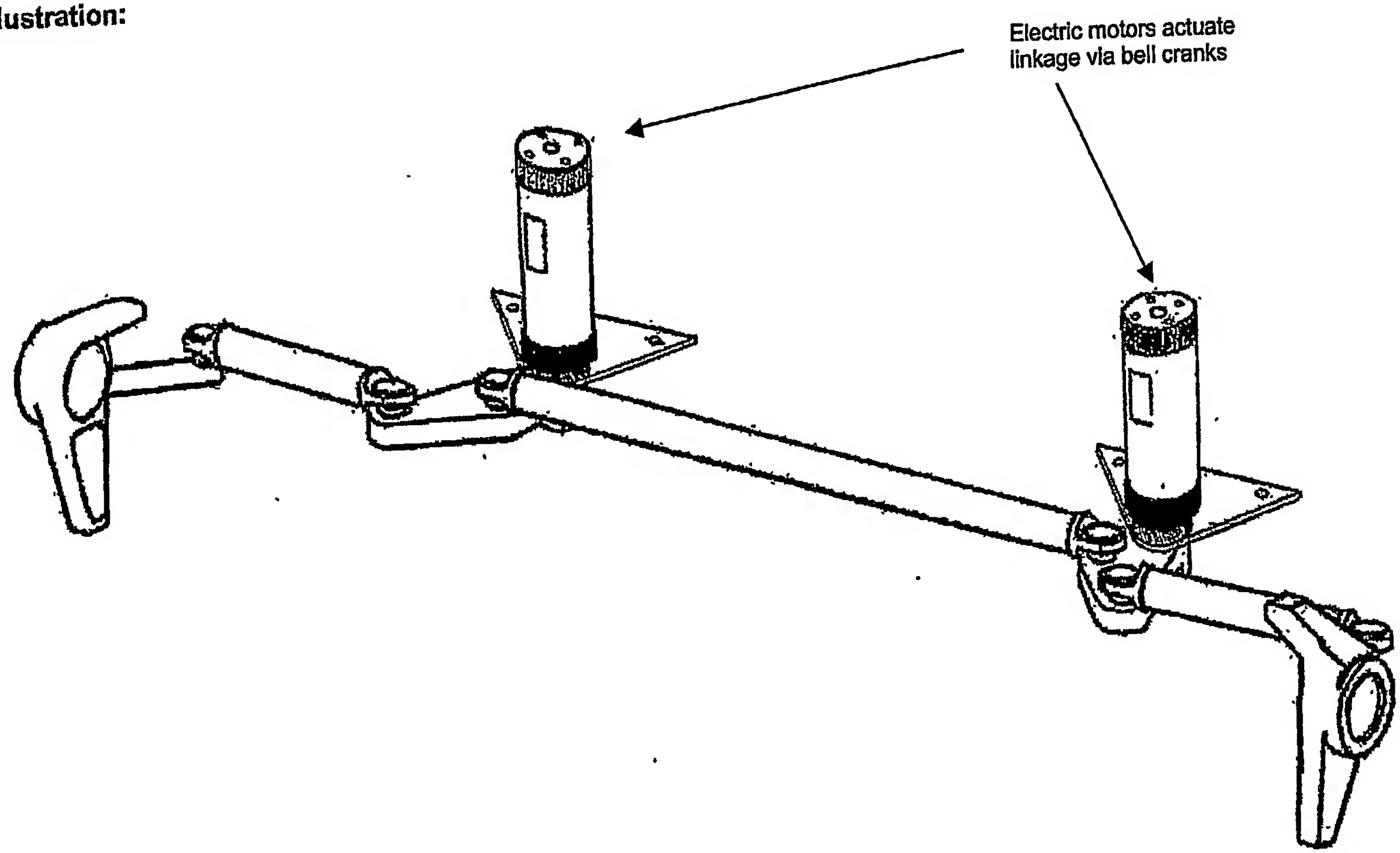

Figure 4: CATIA model of composite steering links and bell cranks connected to steering knuckles which attach to the front wheels. The electric actuating motors would attach to spindles attached to the bell cranks

Detailed description:

The steering input device (this can be any device such as a steering wheel, side stick, yoke, or other) uses sensors to interpret the driver's intentions. This signal is then assessed by the controller to optimize the vehicle dynamics (taking into account the current status of vehicle speed, braking, lateral acceleration, tire contact patch, roughness of terrain, environmental conditions, etc.). The controller then sends commands to the two electric motors attached to a spindle that activates the bell cranks in the steering linkage. These links in turn actuate the front knuckles to physically steer the front wheels. The steering movement is fed back into the controller, along with the other various data sources, to complete the loop.

System Element: Electrically actuated, lightweight, and durable braking system for automobiles

Primary Inventor: Chris Wright (TWR)

Other Inventors: Timothy Moore (HI)

Brief Description:

A braking system for automotive applications that electronically integrates the control and function of independent brake sub-assemblies at each corner of the vehicle with that of the overall vehicle information management and control system. The system comprises control software and operating algorithms, performance monitoring sensors, carbon/carbon brake pads and rotors, and electrically actuated calipers.

Advantages:

While carbon/carbon brakes, made from a composite material comprising carbon fiber reinforcement within a carbon matrix, have potential for performance superior to that of convention brakes, even at reduced mass, they typically are unsuitable for general automotive applications because of their inherent non-linear friction behavior with changes in temperature and humidity. To overcome this limitation, this system incorporates electrically actuated calipers not physically connected to the driver's brake pedal. The benefits of an electrically actuated carbon/carbon braking system include low mass, exceptionally long disc and pad life—possibly lasting as long as the vehicle itself, reduced brake fade, improved consistency of performance relative to driver input, and improved anti-lock capability.

Electrically actuated calipers eliminate the need for a hydraulic system typically including brake lines, seals, brake booster, master cylinder, proportioning valves, and a complex anti-lock fluid pressure modulation system. This enables a significant weight saving, a reduction in system complexity, an array of performance improvements, and attractive life-cycle, maintenance, and environmental benefits.

By enabling the utilization of the lightweight carbon/carbon materials in the rotor and pads, the unsprung mass of the wheel assembly can be reduced, which provides significant benefits to ride, handling, and stability of lightweight vehicles.

The pressure applied by the electrically actuated calipers is continuously variable and can be controlled very precisely, very rapidly, and independently at each wheel, thus enabling improved anti-lock, traction-control, and stability-control functionality. Furthermore, NVH (noise, vibration, and harshness) is also improved by the provision of completely silent and vibration-free anti-lock braking without need for conventional fluid pressure modulation pump and valves.

Electrical actuation of the brakes permits the use of high-performance, low-mass carbon/carbon materials in the rotor and pads of the brake system, which heretofore would have been impractical for non-race applications due to the non-linear friction-temperature/moisture characteristics of these materials.

Features of the innovation:

Carbon-carbon brake rotors (discs) and pads as enabled for general automotive use (*i.e.*, other than racing) by combination with electrically actuated calipers to provide reduced mass, improved peak performance, improved consistency of performance, and extended durability.

Illustrations:

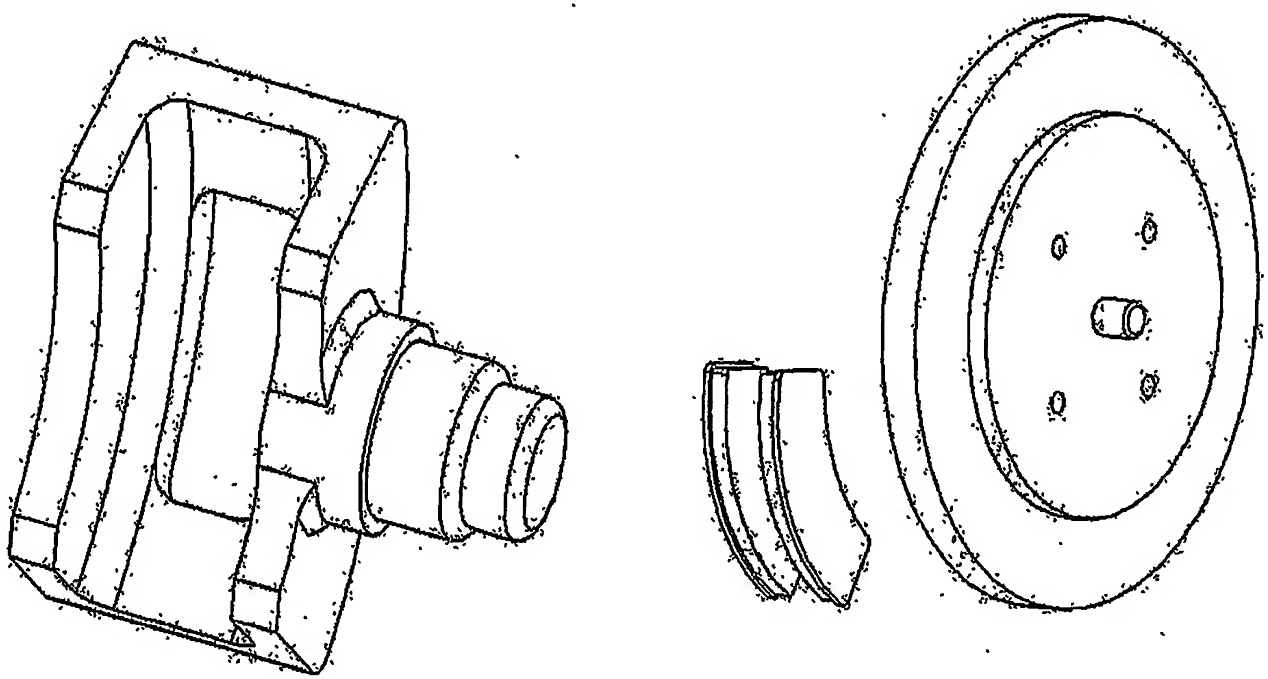

Figure 5: Electrically actuated caliper (left) and carbon/carbon rotor and pads (right)

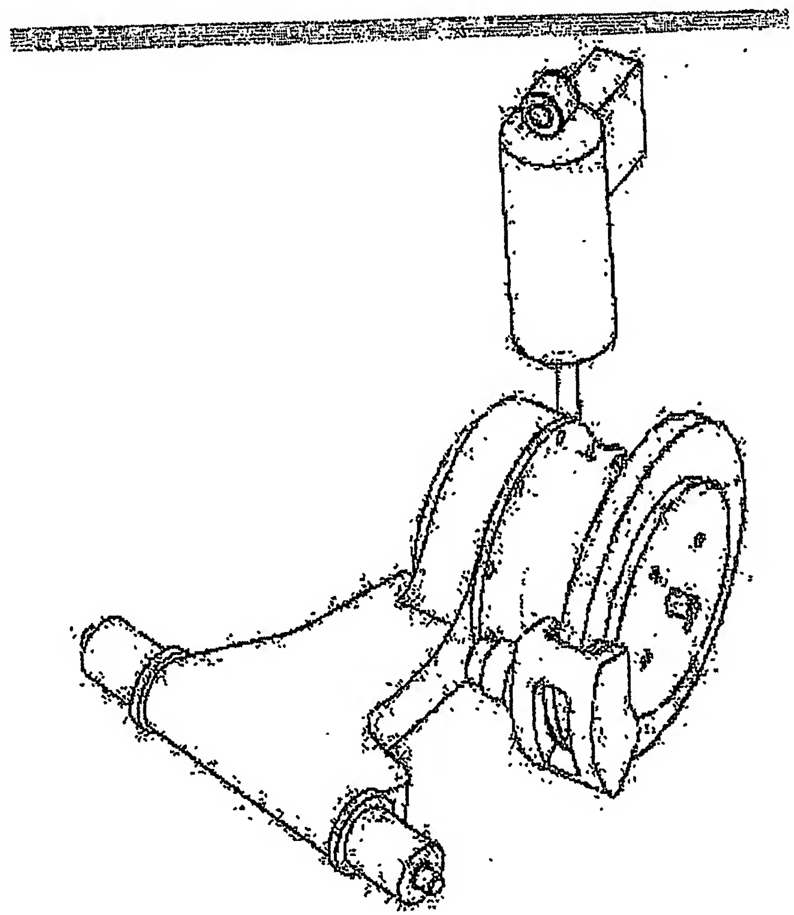

Figure 6: Brake sub-assemblies shown as mounted outboard in relation to rear suspension corners

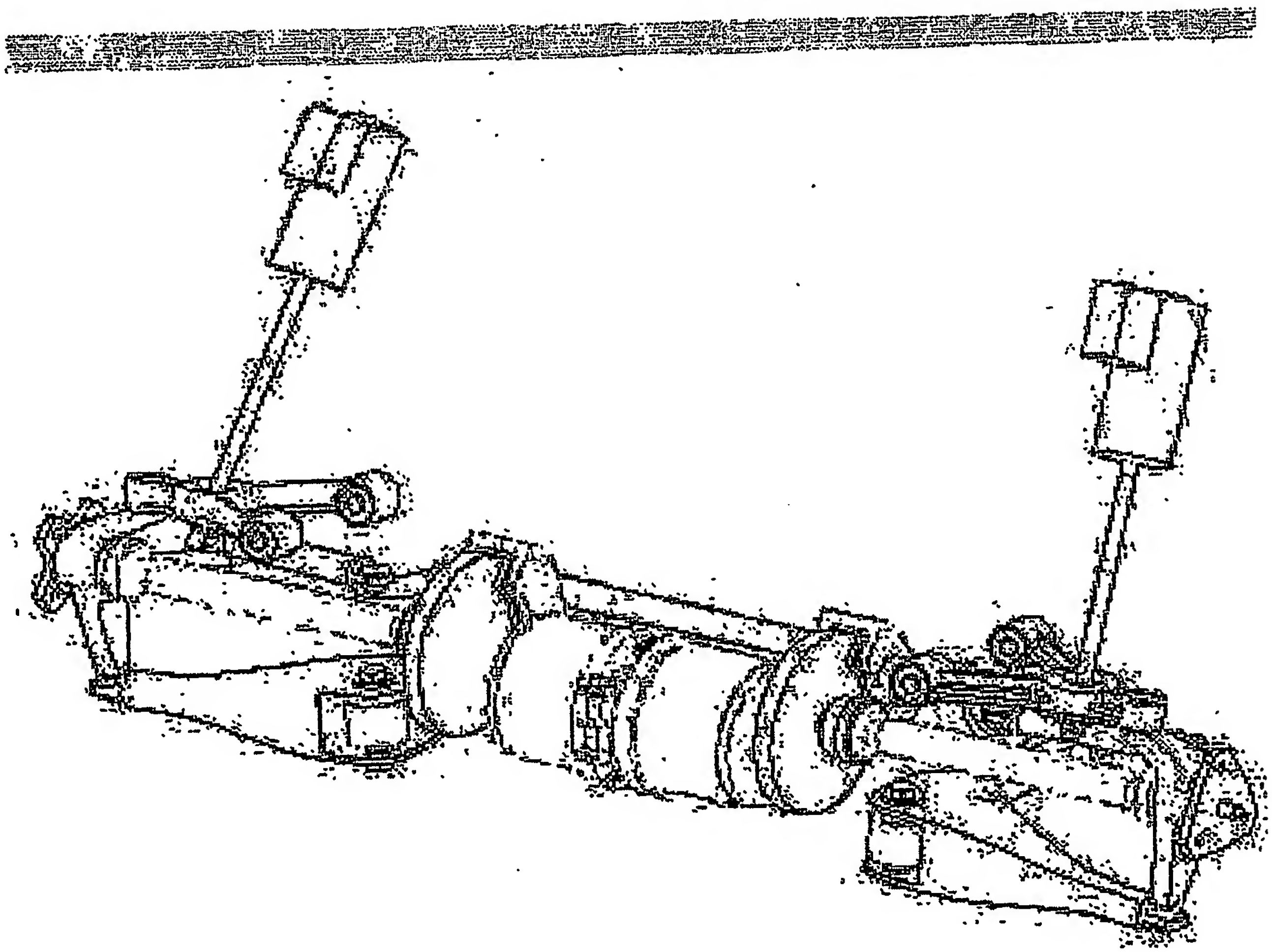

Figure 7: Brake sub-assemblies shown as mounted inboard in relation to both front suspension corners

Detailed description:

The system consists of a pressure sensitive input device (such as a pressure transducer on a brake pedal), brake torque sensors at each wheel (strain gauges on the caliper mounts), wheel speed sensors (typical hall-effect devices), a vehicle deceleration sensor (could access data from g sensor for airbag system), brake rotor and pad temperature sensors (thermocouples), electrically actuated calipers, carbon-carbon pads and rotors (discs), and a central controller. There is no hydraulic link between the driver input and the brake hardware. The system is entirely electric including monitoring, application, and control.

The use of lightweight, high-performance carbon-carbon brake pads and rotors is made possible by the physical de-coupling the driver's brake input from the brake caliper actuation. Driver input is instead translated, via a pressure transducer and controller, into a request for a given rate of vehicle deceleration to be achieved by caliper/pad pressure appropriate for the temperature and moisture content of the brake friction materials. The braking system is tasked with achieving the desired rate of deceleration with an optimal distribution of brake caliper forces and associated braking torque at each wheel.

Based on sensor data for vehicle mass including current payload and mass distribution, vehicle speed, environmental conditions, and pad and rotor temperatures, the system would determine the an initial braking force at each wheel to achieve the desired deceleration from the driver input. Individual wheel speed and brake torque sensors would then provide immediate feedback as to relative effect at each wheel. Caliper forces at each wheel would then be re-optimized based on this feedback in combination with an overall vehicle deceleration force measurement. This process would be repeated in sub-millisecond iterations to provide the closest feasible match of actual vehicle deceleration to the driver's request, compensating for brake friction material status, road surface condition, limits of tire traction, etc.

As a key element of the integrated vehicle dynamics system, the braking system would receive commands from the dynamics controller, which has access not only to brake torque, wheel speed, and rate of deceleration, but also suspension position and steering and yaw angles. The brakes could thereby be applied at each corner of the vehicle as needed to contribute to overall vehicle stability control, even when the driver was not providing a brake system input. Again, the control system would seek to provide the closest possible match to driver intent without allowing the vehicle to enter an uncontrollable skid, slide, or spin.

System Element: Integrated Electromagnetic/Pneumatic Suspension System for Automobiles

Primary Inventor: Timothy Moore (HI)

Other Inventors: Chris Wright (TWR), David Wareing (TWR)

Brief Description:

An electrically and physically integrated electromagnetic/pneumatic suspension that combines an adjustable air spring for variable ride height and spring rates, a continuously tunable pneumatic transverse link to limit body roll, and an actively controlled electromagnetic damping mechanism. This system element incorporates the prior art of Guilden Ltd. (U.K.) and Advanced Motion Technologies (U.S.A.) (hereafter referred to as "AMT") in the form of their electromagnetic linear ram with integrated pneumatic spring. The innovation described herein is an application of and improvement upon that prior art to provide overall control of vehicle ride height, attitude, and stability, with the addition of energy-efficient, semi-active body roll control.

Advantages:

The air spring enables optimization of spring rate, maintenance and adjustment of vehicle ride height with changes in driving conditions or driver preferences, and adjustment of vehicle attitude regardless of the payload or its location in the vehicle. Likewise, the magnetically variable damping and pneumatically adjustable anti-roll link can be tuned for changes in gross vehicle weight, speed, traction conditions, roughness of terrain, and driver preference. Damping, spring rate, and anti-roll stiffness together can be controlled by the vehicle's central information management and control system, thereby allowing high resolution and fast optimization of suspension characteristics under different dynamic conditions.

In addition to the improvements in overall vehicle characteristics, further advantages of this innovation are a significant reduction in this system element's contribution to total vehicle weight and improvements in vehicle tailorability and upgradability. These parameters are crucial to success in the increasingly competitive sales environment in terms of initial sales, resale, and life cycle cost reduction.

Features of the innovation:

This innovation applies the AMT linear ram technology to lightweight vehicles to overcome the challenge of providing consistent driving dynamics over a wide range of vehicle gross mass and driving conditions with a minimum of energy consumption, cost, and complexity. The integrated control system continuously adapts ride height and spring, damping, and anti-roll characteristics to payload, driver inputs and preferences, and road conditions. Furthermore, this innovation permits semi-active variable anti-roll characteristics with minimal energy consumption, and without the over-sizing of the linear rams that would result from attempting to counter all body-roll forces via the ram's electromagnetic damping.

Detailed description:

This integrated automotive suspension comprises a set of four AMT pneumatic/electromagnetic linear-ram suspension struts, a pneumatically variable transverse link at each axle, and a digital control system with links to other vehicle sub-systems. The innovation includes control parameters, component specifications, and configuration to provide—with minimal energy consumption and in some cases net energy gains—the simultaneous semi-active optimization of suspension in response to driver preferences and transient inputs, payload mass and distribution, road surface, and aerodynamic forces.

The AMT linear rams consist of a variable air spring and variable electromagnetic damper. The pressure in the air spring can be increased or decreased to change the static strut length under load and to adjust the spring rate. The electromagnetic resistance load in the damper can be varied in under one millisecond, or up to 1,000 times per vertical cycle of the strut piston. The overall suspension system takes advantage of the widely and, in the case of damping, rapidly variable characteristics of these AMT components.

The struts are then linked transversely (across the vehicle) to counter body roll. The link itself is isolated, such that a failure that might compromise anti-roll stiffness would not affect pneumatic springs. Hydraulic elements connect the variable pneumatic element at the center of the transverse link to the left and right struts. (This can be done pneumatically as well.) The stiffness of the transverse link is then adjusted by varying the pressure in the isolated pneumatic segment, either by adding pressure from a pre-pressurized reservoir or by venting excess pressure. Diaphragms with relatively large surface area reduce the pressure required in the variable pneumatic portion of the roll-control link. Anticipated working pressure is on the order of 60–120 psi. Thus, minimal energy inputs are required for tuning the anti-roll characteristics with changes in driver preferences, payload, quasi-average vehicle speed, and road surface conditions. The peak power associated with the frequent tuning of this system is further reduced by the use of a reservoir, and therefore a smaller pump. Control of fast transients in body roll and pitch is then augmented by rapidly varying the damping rate—or degree of powered actuation—of each individual electromagnetic strut during acceleration, braking, cornering, and aerodynamic inputs.

This solution for semi-active variable control of body roll permits downsizing the AMT electromagnetic rams to meet only the requirements of damping fast-transient bump, pitch, and roll inputs, thus augmenting the tunable pneumatic anti-roll system just as they augment the pneumatic springs. As a result, energy consumption associated with the continuously-variable control of body roll is expected to be well below what would be required if all roll control were accomplished via the electromagnetic rams alone and/or with rapid and frequent adjustment of the pneumatic springs.

Vehicle ride height is adjusted via the air springs either in direct relation to driver selection of settings (*e.g.*, for rough terrain or deep snow) or automatically to compensate for changes in payload mass and/or distribution and averaged vehicle speed (*e.g.*, automatically defaulting to normal height over a set rough-terrain maximum of 35 mph, and then lowering further at highway speeds of 55 mph or higher). Changes in ride height would be executed over a period on the order of 5–15 seconds (depending on the magnitude of change) to avoid disrupting passengers and to minimize energy consumption and pump or reservoir capacities. Spring rates are thus also adjusted with load on the vehicle and on each of the four suspension struts.

Both the stiffness of the transverse anti-roll links and the default electromagnetic resistance load on the dampers is adjusted in keeping with payload mass and distribution and driver preferences (*e.g.*, for extra nimble handling or emphasis on ride comfort). These anti-roll and damping characteristics are then continuously varied—still as a semi-active function—with driver acceleration, braking, and steering inputs. Electromagnetic damping characteristics are then further varied, in a sub-millisecond timeframe, to compensate for real-time vehicle dynamics and road inputs. Finally, active control of and power input to the linear rams can, just as rapidly, apply forces to further counter dynamic inputs.

All key suspension variables would then be controllable via a stability-control algorithm in the vehicle's central information management and control system, which optimizes the behavior of each strut according to real-time dynamic conditions and driver inputs. The control system draws upon input from driver preference settings; acceleration, braking, and steering inputs; vehicle speed, mass, and payload-distribution data; and feedback from sensors detecting the real-time dynamics of the vehicle, road surface conditions, and aerodynamic forces (such as cross winds) as a function of wheel speeds, yaw rates, slip angles, and suspension travel.

Illustrations:

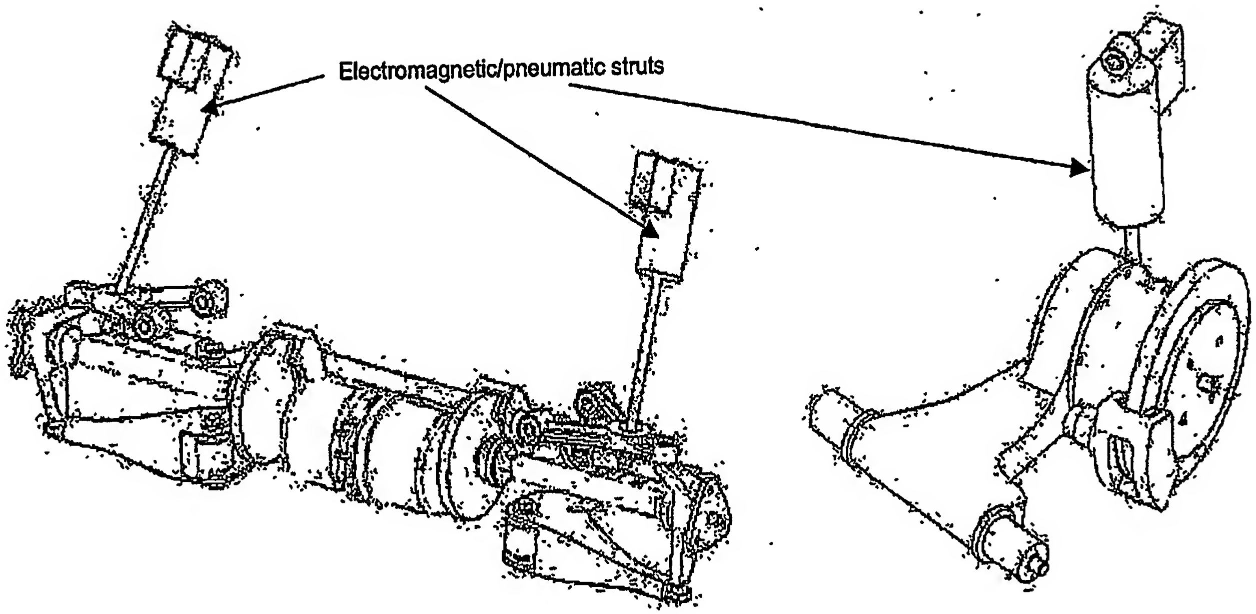

Figure 8: Electromagnetic/pneumatic strut as applied to both front (left) and rear (right) suspension assemblies

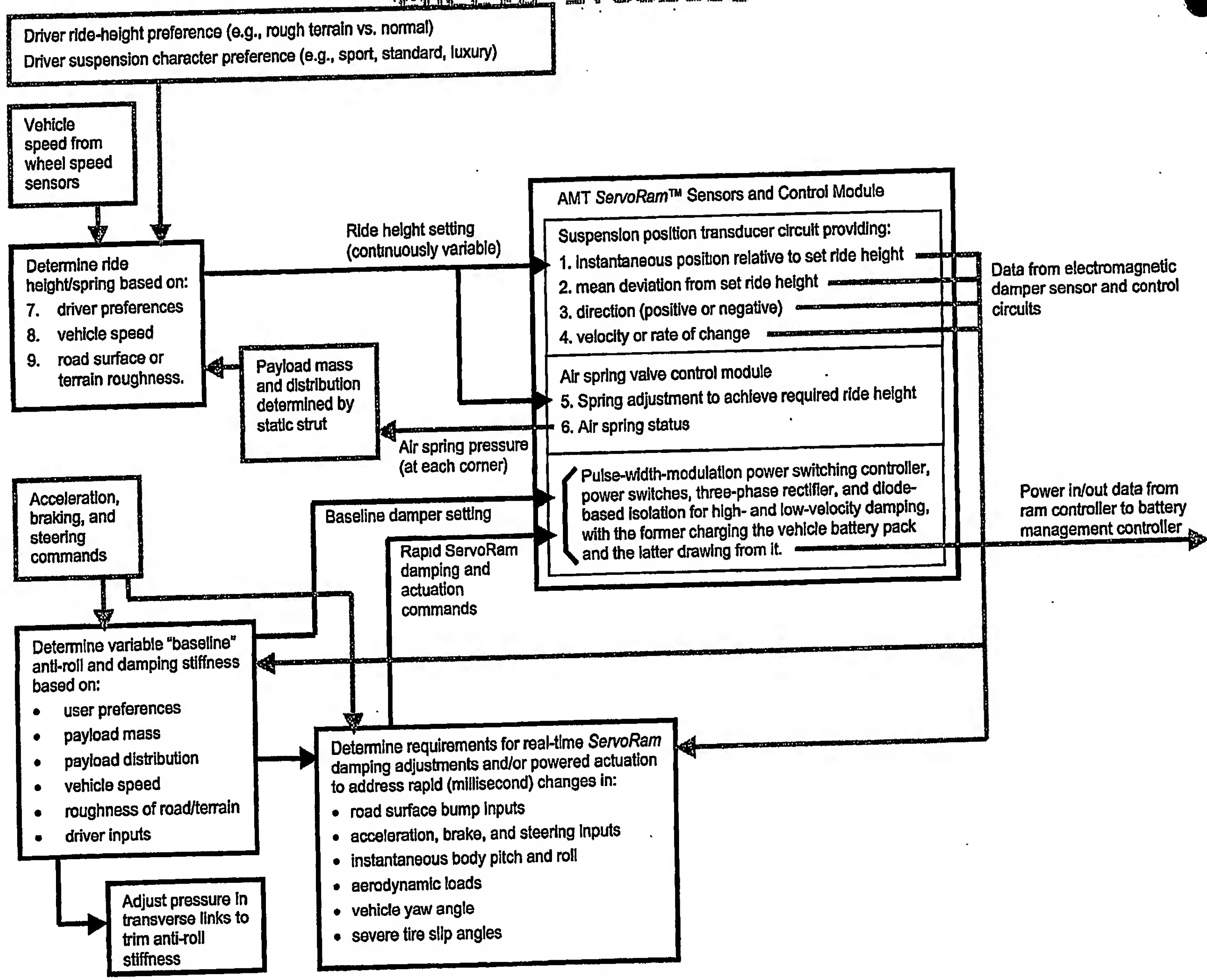

Figure 9: Control schematic for variable pneumatic springs and anti-roll systems with electromagnetic damper/actuators

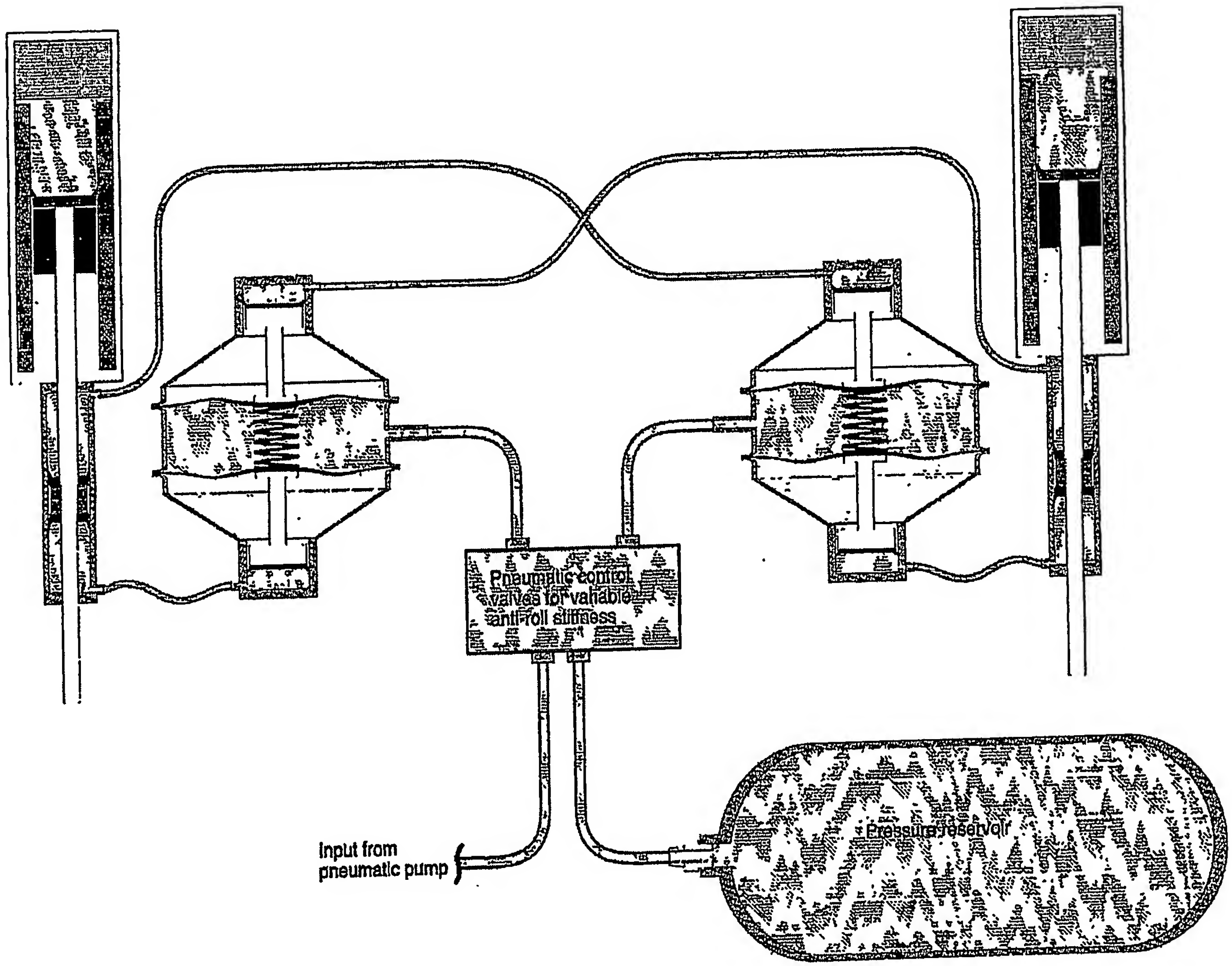

Figure 10: Continuously variable pneumatic anti-roll links and the hydraulic circuits connecting them to the electromagnetic/pneumatic strut

System Element: Innovative Design and Production Approach for Lightweight Composite Automotive Suspension Components

Primary Inventor: David F. Taggart (HI)

Other Inventors: David Cooper (TWR), Chris Wright (TWR)

Brief Description:

A design and production approach for advanced composite suspension components that incorporates specific design and processing features which contribute directly to improved vehicle performance and affordable component production.

Advantages:

Existing competing products are typically mass-produced steel or aluminum components. While these products perform exceedingly well over the lifetime of the vehicle, they are typically heavy and compromise weight and optimal performance for durability and low cost. The approach described by this system element provides for a significantly lighter weight component with equivalent durability and the potential for competitive cost.

Suspension components constructed of advanced composite materials (carbon fiber reinforced thermoplastic in this case) are considerably lighter and can provide improved stiffness over conventional metal components. This is an advantage as it reduces unsprung mass which has proved to be a critically important aspect in the design of lightweight vehicles for acceptable ride and handling. Improved stiffness in the suspension component also gives greater control of compliance in the overall suspension of the vehicle as each component can be better tailored to its particular role. Advanced composite suspension components also enable optimized structural shaping for the applied loads and surrounding packaging, thereby providing additional design freedoms.

This innovation may be applied to most swingarm type suspension components provided their application is considered from the outset of the vehicle design effort, and accommodation provided in an appropriate fashion.

Features of the Innovation:

This design is part of a practical automobile suspension solution that uses advanced composite materials and is producible with an economically acceptable volume production process (e.g. 50,000 vehicle sets per year or more). It incorporates tailored reinforcement and co-processed metallic interfaces. In particular, the unique aspects of this innovation are the application of a large included volume (LIV) design philosophy that plays to the positive attributes of composite materials by avoiding locally complex design features, maximizing the moment of inertia of the component's cross-section, and maximizing the component's long-term durability by reducing the applied load on the component. Further features include the use of large diameter bonded metallic interfaces to facilitate low load concentration transfer of applied loads, and the incorporation of conventional automotive bushings to avoid the cost of custom designed bushings.

Illustrations:

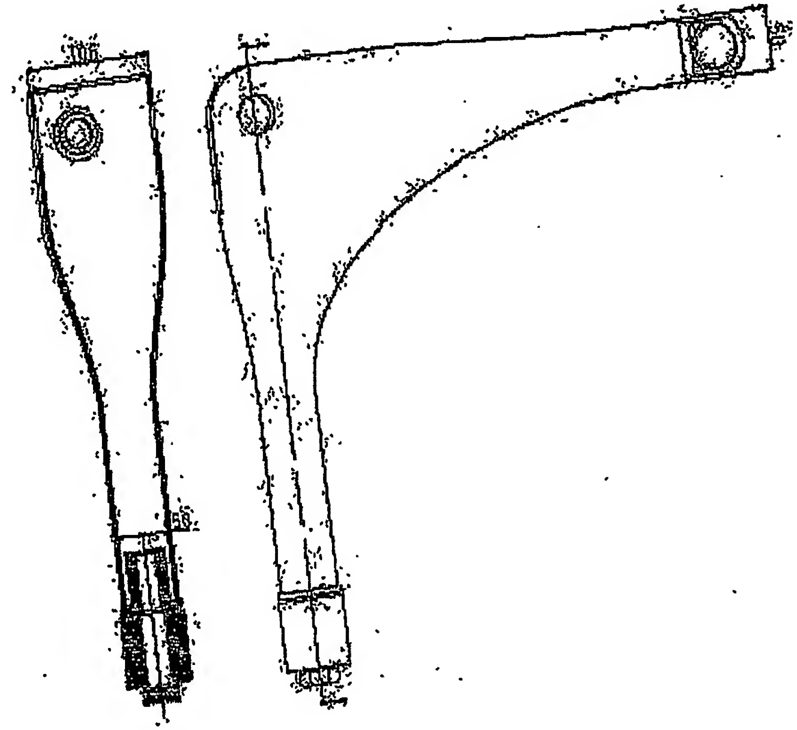

Figure 9: Detailed engineering drawing of the carbon reinforced composite lower suspension arm (or A-arm)

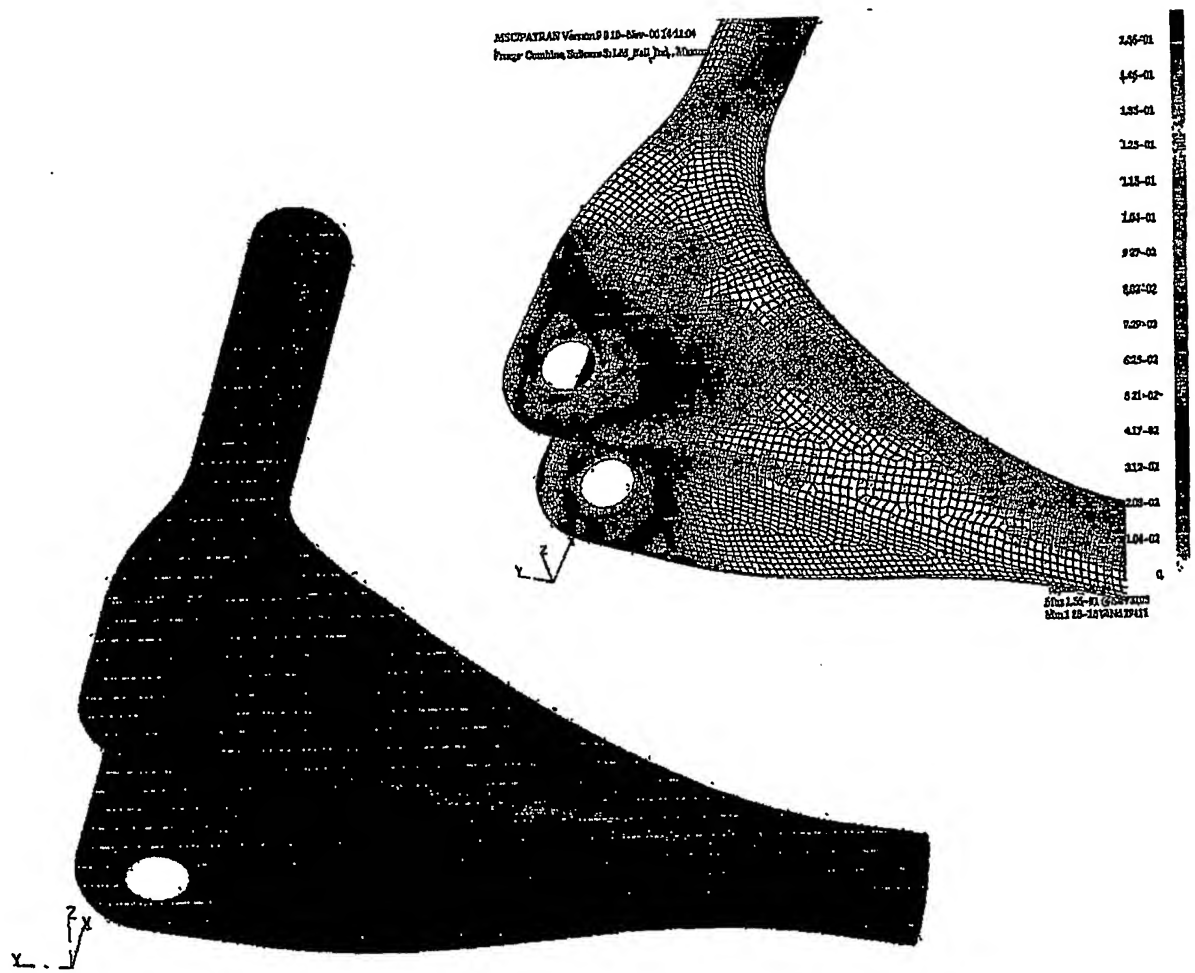

Figure 10: Solid and finite element models (right) of the carbon reinforced composite lower suspension arm (or A-arm)

Detailed description:

The innovation consists of a specific design strategy and interdependent production approach. The design strategy consists of integrating "large included volume" (LIV) shaping to managing loads, bonded metallic inserts to manage mechanical interfaces, and tailored reinforcement to manage internal loads and provide desired durability.

The LIV philosophy imposes simple, high moment of inertia shaping to a component to best exploit the advantages of carbon-reinforced polymers in terms of structural efficiency and ease of processing. Components typically have closed cross-sections that approach maximum internal volume for a given surface area. In the case of suspension components, this is quite different than competing component design using metals which typically use solid components with open cross-sections as is typical of stamped sheet metal.

All mechanical interfaces include a simple, large diameter, sleeve type single lap bonded metallic bushings or inserts. This is a very simple and reliable solution to an often complex problem of having to locally transfer loads from one interfacing structure to another. The use of bonded inserts enables a very simple geometric interface for the composite, contributing to low cost and structural efficiency, while using a metal detail to transfer the loads from the mating detail into the composite component in as efficient manner as possible, and insuring uniform load distribution into the composite material.

The use of tailored reinforcement via cut and kit performs enhances the components ability to manage the applied loads in as efficient manner as possible, while being careful to not introduce additional cost into the production process.

System Element: Modular Rear Suspension and Traction Motor Unit for Automobiles

Primary Inventor: David Cooper (TWR) and David F. Taggart (HI)

Other Inventors: Chris Wright (TWR), Timothy Moore (HI)

Brief Description:

A carbon fiber reinforced trailing arm type suspension component that functionally integrates the structural attachment for an integrated motor and gearbox, and serves as the primary structural member between the wheel and the vehicle. Designed to be modular, this unit can be removed and fitted with either a wheel with integrated wheel motor and brakes or a wheel/brake system only.

Advantages:

The design and fabrication approach results in a very lightweight component and thereby reduces unsprung mass. The component will be stiffer structurally than a conventional trailing arm component, and therefore will enable optimization of the design for minimum intrusion into the interior volume of the vehicle. By integrating the traction motor with the gearbox, knuckle and spindle, a significant reduction in parts count is achieved, with commensurate production

cost savings and weight reduction, while negating the need for driveshafts and their associated efficiency losses.

Features of the innovation:

Produced practical automobile suspension components from advanced composite materials using an economically acceptable volume production process (e.g. 50,000 vehicle sets per year or more) suitable for suspension components incorporating tailored reinforcement and co-processed metallic interfaces. In particular, the unique aspects of this innovation are the application of a large included volume (LIV) design philosophy that plays to the positive attributes of composite materials by avoiding locally complex design features, maximizing the moment of inertia of the component's cross-section, and maximizing the component's long-term durability by reducing the applied load on the component. Further, unique features are the use of large diameter bonded metallic interfaces to facilitate low load concentration transfer of applied loads, and the innovative incorporation of conventional automotive bushings to avoid the cost of custom designed bushings.

cost savings and weight reduction, while negating the need for driveshafts and their associated efficiency losses.

Features of the Innovation:

Produced practical automobile suspension components from advanced composite materials using an economically acceptable volume production process (e.g. 50,000 vehicle sets per year or more) suitable for suspension components incorporating tailored reinforcement and co-processed metallic interfaces. In particular, the unique aspects of this innovation are the application of a large included volume (LIV) design philosophy that plays to the positive attributes of composite materials by avoiding locally complex design features, maximizing the moment of inertia of the component's cross-section, and maximizing the component's long-term durability by reducing the applied load on the component. Further, unique features are the use of large diameter bonded metallic interfaces to facilitate low load concentration transfer of applied loads, and the innovative incorporation of conventional automotive bushings to avoid the cost of custom designed bushings.

Illustrations:

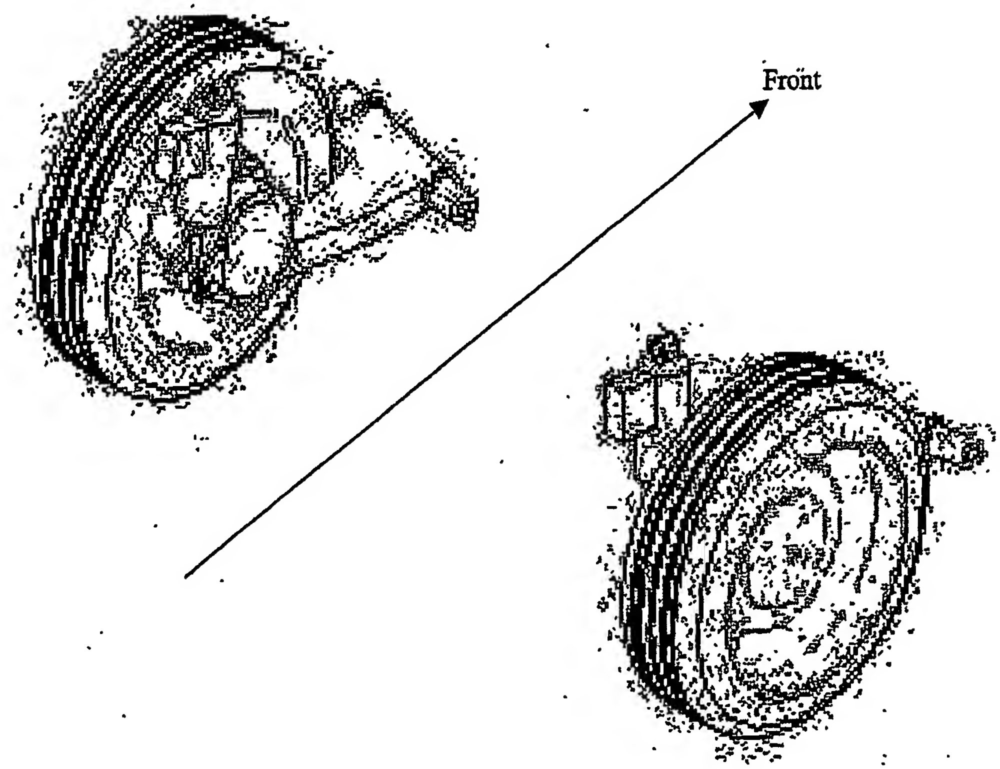

Figure 11: Rear suspension module with wheel attached

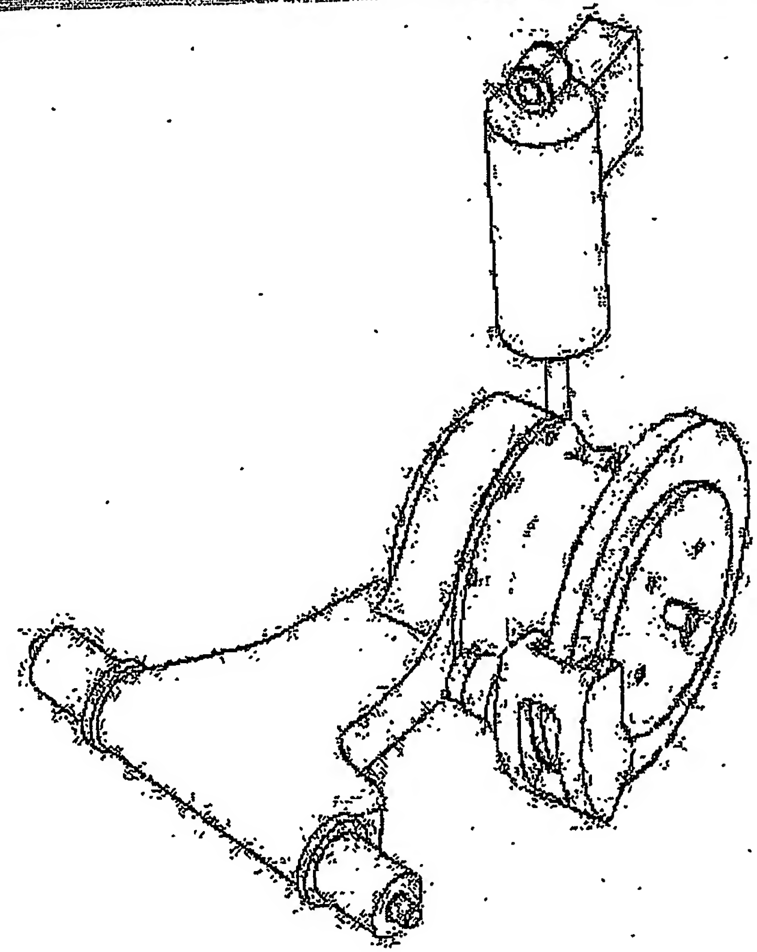

Figure 12: Rear suspension module as a separate module including composite trailing arm, brakes, motor, transmission, and suspension strut

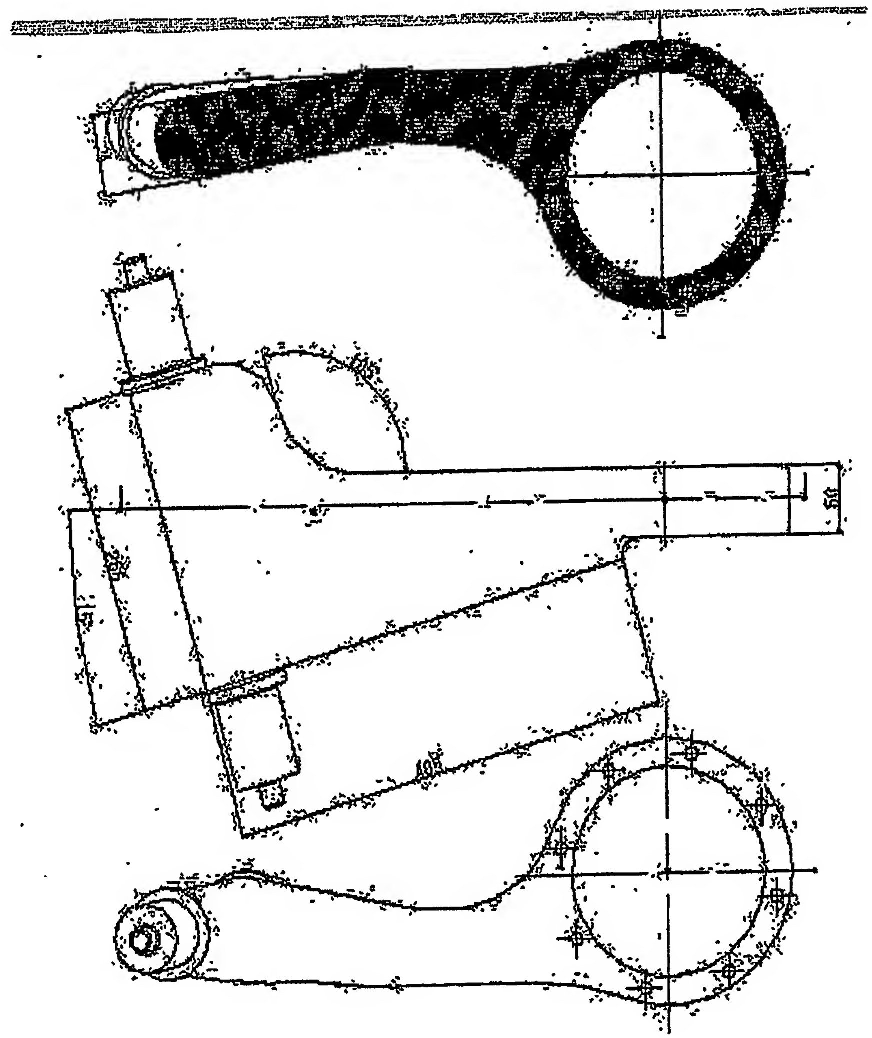

Figure 13: Engineering drawing of the composite trailing arm by itself showing key interface details and integrally molded bushing

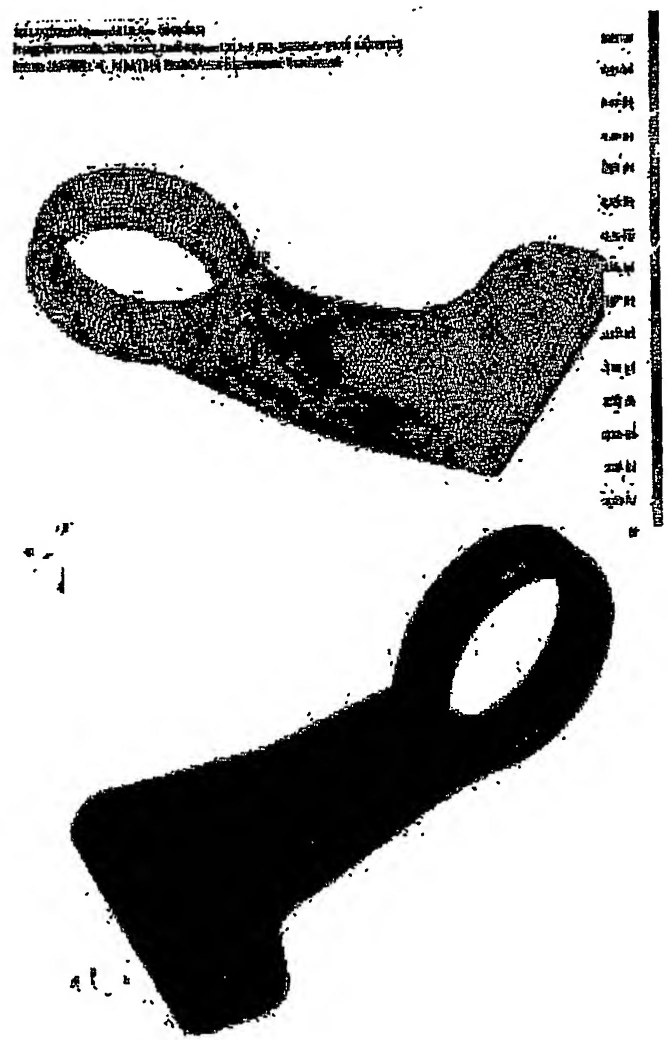

Figure 14: Solid model of the composite trailing arm by itself showing key interface details and integrally molded bushing

Detailed description:

Attached to the composite rear trailing arm is a hub motor and step down epicyclic gearbox in series. The motor and the gearbox are designed to dispense with the need for a conventional knuckle, half shaft, and spindle. The trailing arm component is made from carbon fiber reinforced polymer and incorporates the housing for the motor.

System Element: Active Tire Contact Patch Control System to Manage Rolling Resistance and Dynamics of Automobiles

Primary Inventor: David F. Taggart (HI)

Other Inventors: David Cramer (HI), Chris Wright TWR), Timothy Moore (HI)

Brief Description:

On board sensors monitor a range of vehicle parameters to actively optimize tire rolling resistance and contact patch geometry resulting in an overall improvement in vehicle efficiency and safety under a wide range of operating conditions.

Advantages:

Conventional tire pressure monitoring systems generally comprise a pressure and temperature sensor which simply feeds back to the driver to provide a warning should a tire start to lose pressure. The innovation proposed herein would also need to perform this function. But with the addition of the vehicle's digital dynamics controller, which is part of the vehicle's central information management and control system, this innovation uses an active tire pressure monitoring system to feed back information about where the tire contact patch is on its performance map. This additional functionality, combined with information from other vehicle sensors already in the vehicle, which includes wheel speed sensors, accelerometers and air spring pressure sensors, enables the dynamics processor to tune the dynamic parameters of the vehicle for optimum stability and efficiency at any point in the performance map of the vehicle. This will result in improved braking response and shorter braking distances, improved steerability, traction and ride under wider road conditions and driver inputs. It will also ensure that the tire is kept inflated correctly to optimize fuel consumption and safety.

Features of innovation:

This innovation integrates a tire pressure monitoring system into the overall dynamic control of vehicle by dynamically changing air pressure within the vehicle and thus tire contact patch.

Detailed description:

Sensors embedded in the tire and around the vehicle monitor tire pressure and temperature, vehicle mass and center of gravity, traction, and environmental data and report that data to the vehicle's central information management and control computer. The computer utilizes a vehicle dynamics and stability algorithm to interpret that data combined with the driver's input, and actively increase or decrease the tire pressure to match that pressure and the prevailing input data

to optimize the contact patch geometry that the tire makes with the road surface to provide the optimum combination of rolling resistance and traction, thereby optimizing overall vehicle efficiency and safety. The innovation consists of sensors, wiring infrastructure, and computer algorithms and application software.